Wildland-Urban Interface Fires

NIST:

Experiments	**Modeling**
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The Problem

- The frequency of fires in the Wildland-Urban Interface (WUI) that threaten communities is likely to increase due to:
  - Increasing pace of WUI development (doubled in last 20 years)
  - Increasing acres burned by wildland fires (nearly doubled in last 10 years)

Photo by JOHN GIBBINS / Union-Tribune
Cedar Fire about to engulf the Scripps Ranch residential community

- Of the 10 largest fire loss incidents in US history, 4 occurred pre-1907 and 4 were WUI fires - all within the last 15 years.

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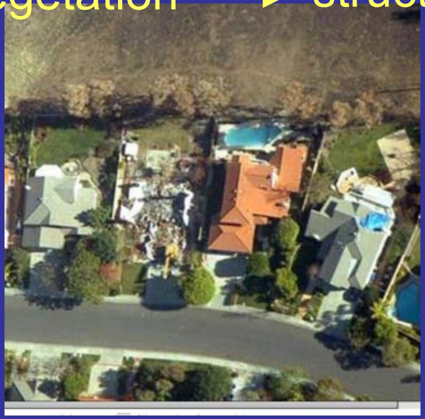
Types of WUI Fire Spread

vegetation → vegetation


Photo by JOHN GIBBINS / Union-Tribune
Cedar Fire about to engulf the Scripps Ranch residential community

vegetation → structure



structure → structure

- convective & radiative heat transfer
- firebrands: generation, transport, deposition, and subsequent ignition of target fuel

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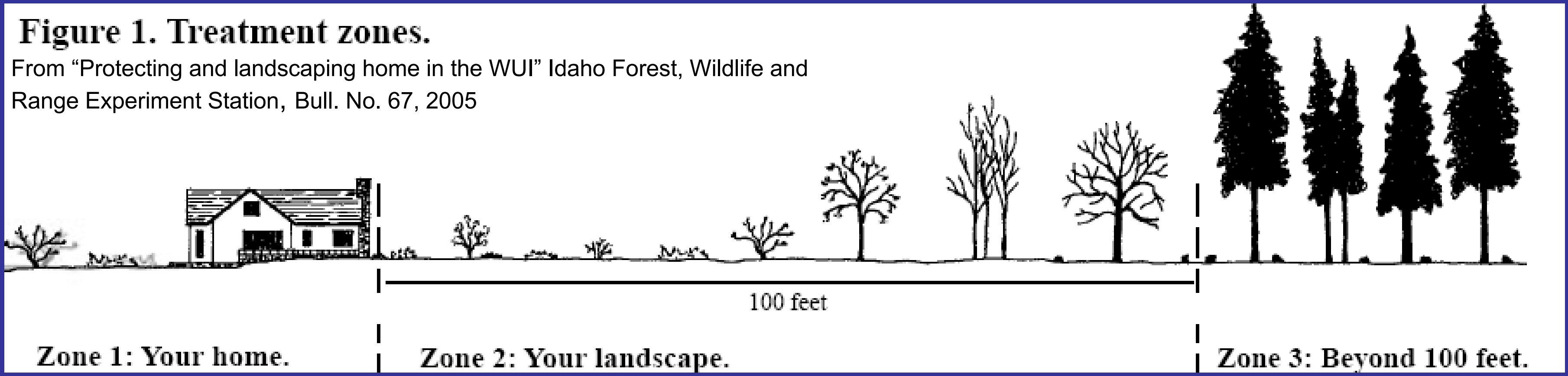
Current Approach to Community Risk Mitigation: Wildland-Fuel Treatments

- Reduce wildland fuel loads (fuel treatments)
  - 60% ($300M) of USFS fuel treatment budget is spent in high priority WUI areas.
  - Less than 5% of fuels are treated per year!
- Treatments are based on limited scientific study and fire behavior modeling.

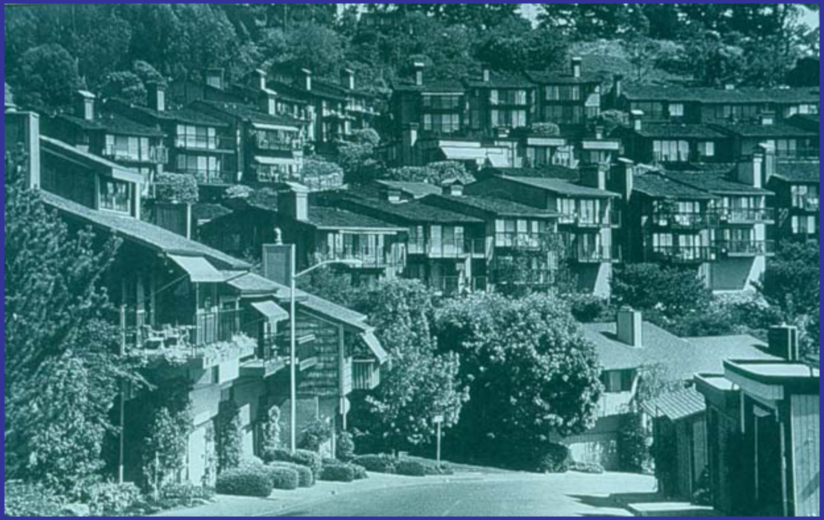
Photo by JOHN GIBBINS / Union-Tribune
Cedar Fire about to engulf the Scripps Ranch residential community

Current Approach Home Risk Mitigation: Defensible Space Around Home



- Focus is on limiting radiative and convective heat flux on home from vegetative fires.
- Based on worst case scenario estimates from observations and limited experiments.
- Structural ignition from firebrands is not well studied.

Structure Density is Important



Berkeley Hills before

Berkeley Hills after 1991 fire

From "Fire in Utah's WUI," M. Kuhns, Utah State University

What's Lacking?

- Systematic evaluation of risk assessment / mitigation approaches.
- Do this through targeted experiments and a range of physics based fire spread models.
- Some key issues:
  - role of firebrands
  - impact of housing density
  - effectiveness of fuel treatments

Wildland-Urban Interface Fire Project Overview

Experiments

Trees

UCR / USFS

Ladder fuels

BRI

Firebrands

U. of FL; USFS; CSIRO

Shrubs

Surface fuels

Field measurements

FERIC

Forest burns / Fuel treatments

CDF

WUI building standards

Tool Development

- Fire behavior models
  - physics based
  - range in complexity
- Vegetation/structure database
  - flammability ratings

WUI fuel mapping (*Coeur d'Alene)*

Tool Capabilities

- Fire behavior and smoke movement predictions
- Risk assessment and mitigation
- Provide scientific basis for WUI building standards and codes

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WUI Fires: Range of Processes and Scales

10^5 ----------10^4 m------------- 10^3 m-----------10^2 m -----------10 m ---------1 m --- 10^{-3} m

smoke movement

Photo by JOHN GIBBINS / Union-Tribune

Cedar Fire about to engulf the Scripps Ranch residential community

regional

flame spread and ignition

community

basic fuel elements

Two Levels of WUI Modeling at NIST

LEVEL 1 – Community Scale – WFDS – development & validation underway

- 100 s of meters domain size
- More detailed physics-based fire behavior (e.g., strategic planning)

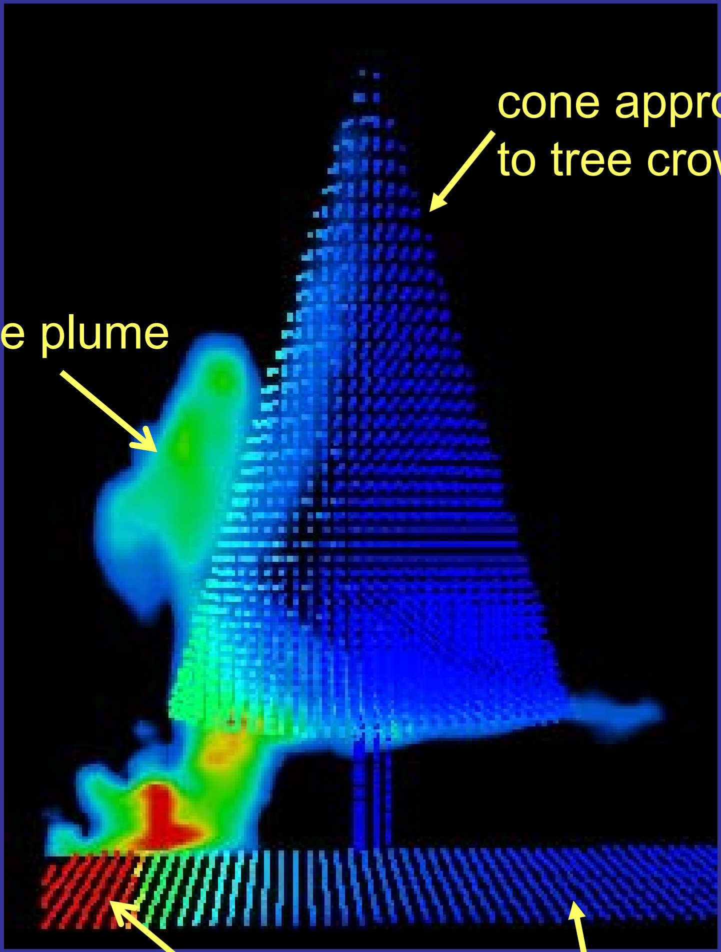
LEVEL 2 – Landscape Scale – development starting in 2007

- 1000s of meters domain size
- Relatively more semi-empirical based fire behavior
- Fast turn around time on simulations (e.g., aid responders)

WFDS Examples

- Isolated Douglas fir tree burn laboratory experiments
- Crown fire initiation laboratory experiments
- Crown forest fire field experiments

WFDS Example:
Snapshot of Surface Fire Spreading Under Conifer



- Three dimensional
- Time dependent
- Radiative and convective heat fluxes drive thermal degradation of vegetation.
- Drag of vegetation on air flow
- Smoldering combustion is not currently modeled

NIST Douglas Fir Tree Burns

- **Douglas Fir**
  - Range of heights: 1.5 m – 5 m (4’ – 17’)
  - Different moisture regimes
  - Measured
    - Mass loss
    - heat release rate
    - gas temperature
    - heat flux
  - Firebrands collected

2.4 m tall tree

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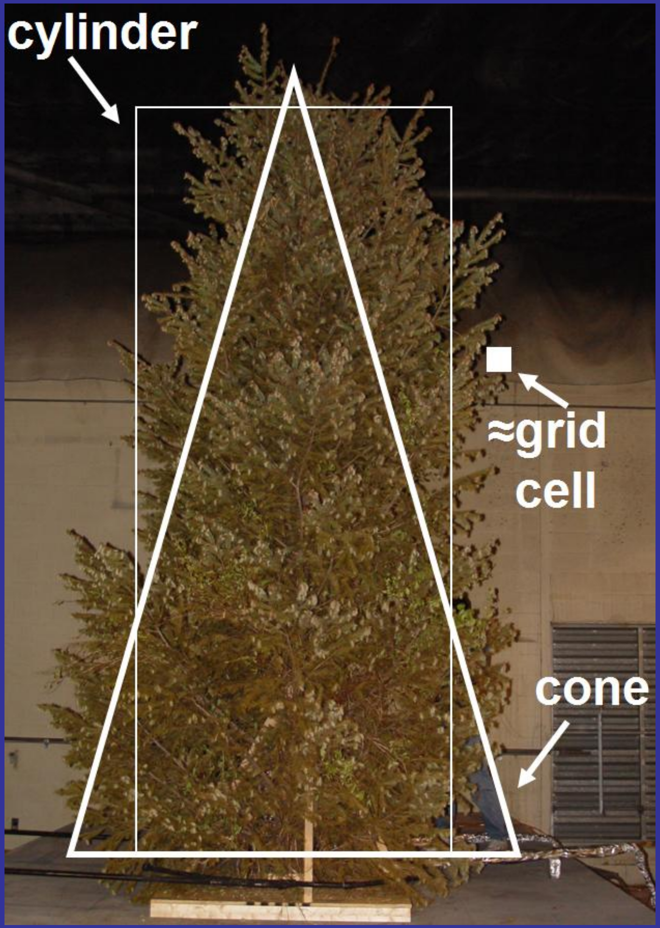
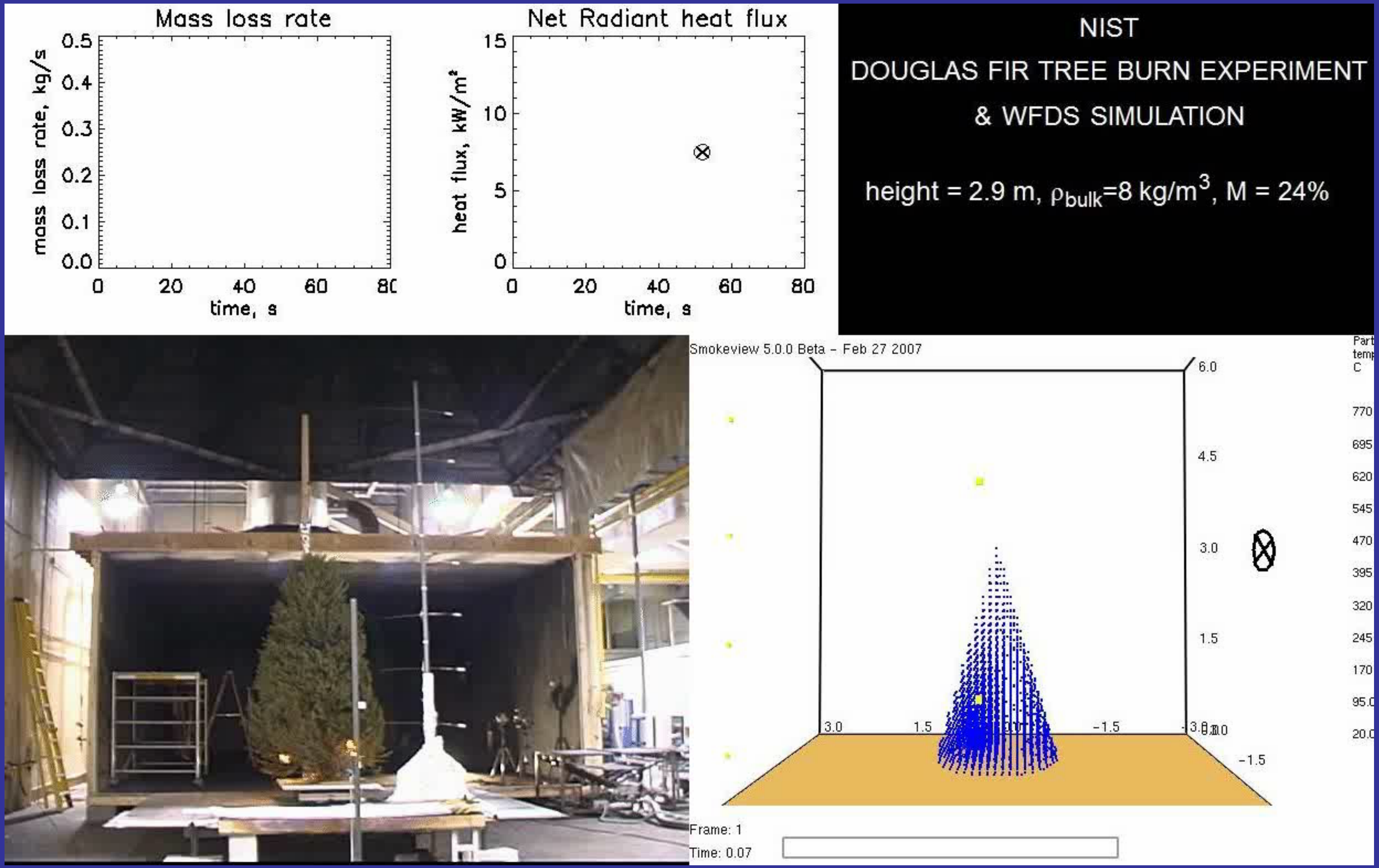
Assumptions for Tree Burn Simulations

- Tree crown is cone or cylinder
- Uniformly distributed mass

4.5 m tall Douglas fir



Movie of Experimental and WFDS Tree Burn



- 9 cpu hours for 60 s
- grid cell = 7.5 cm; 512,000 cells

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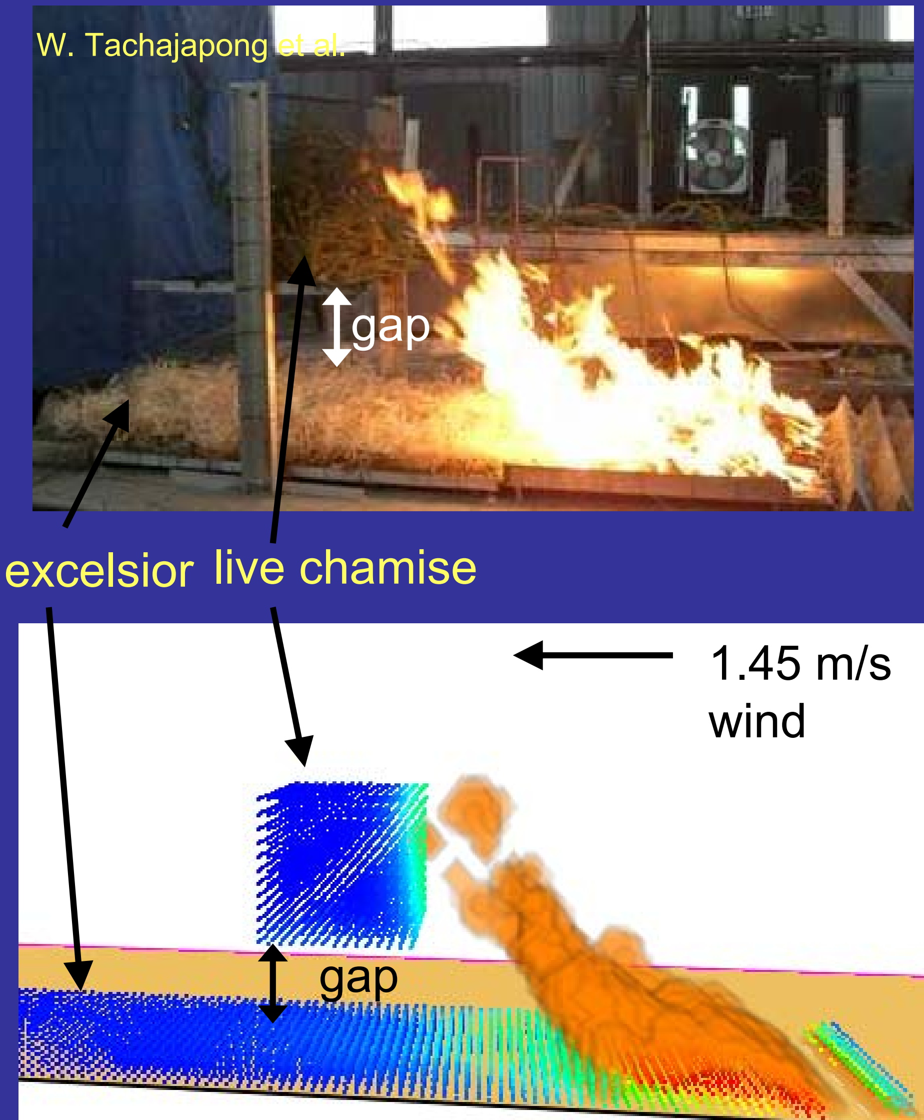
Forest Fire Lab (Riverside, CA)
Crown Fire Initiation Experiments

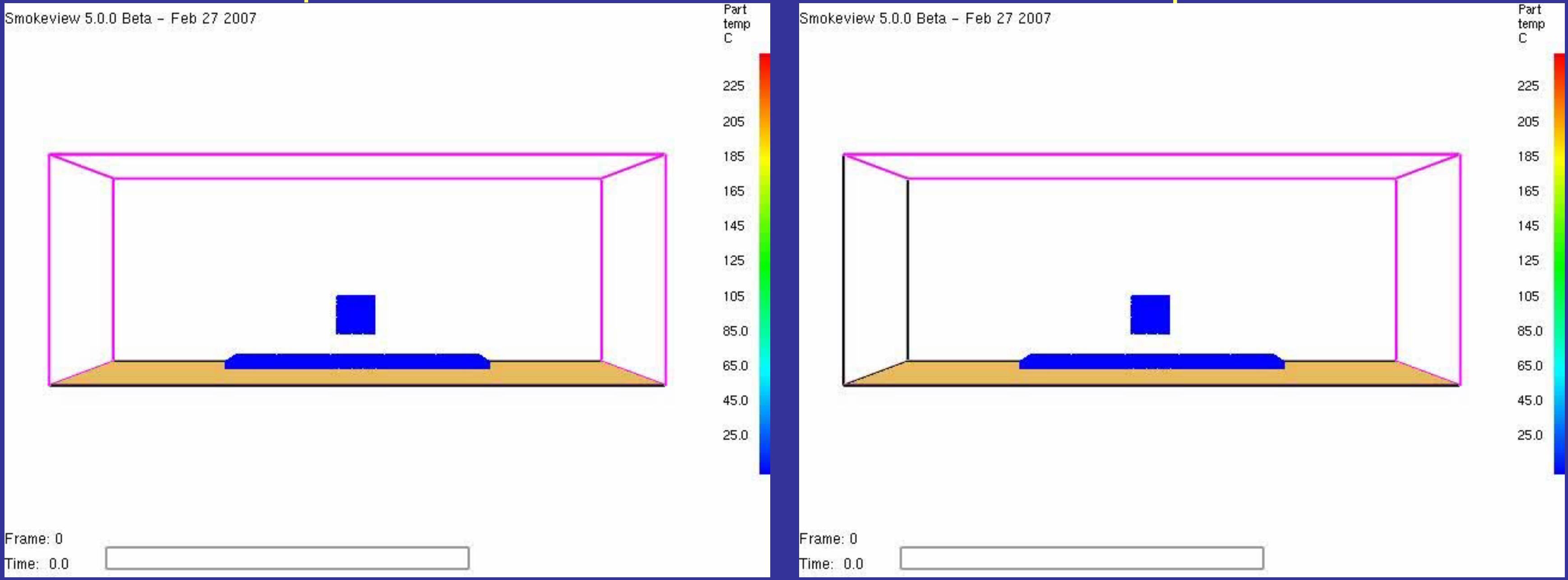


- Isolated clump of elevated vegetation.
- Represents a post-thinning environment.
- Wind speed and vertical gap between surface and elevated fuels are changed.

Example of WFDS Simulation of Crown Fire Initiation Experiment

no imposed wind

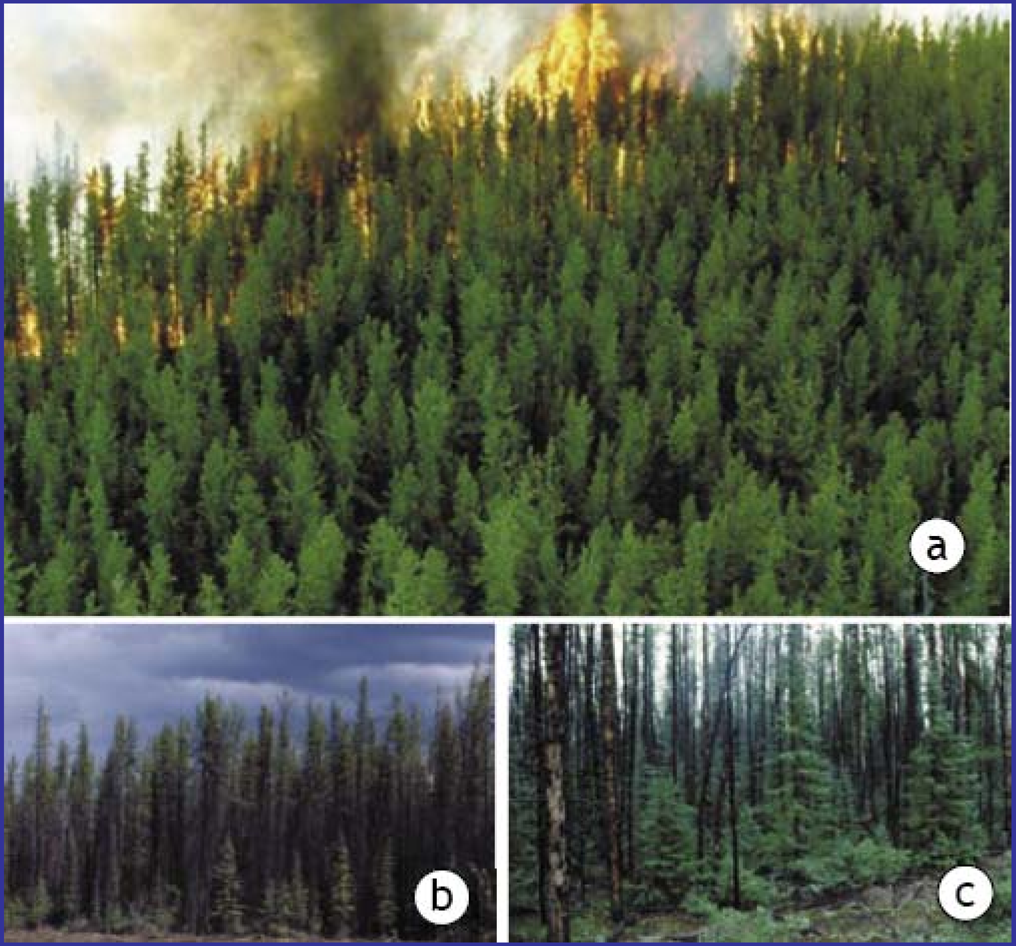
1.45 m/s imposed wind



- Excelsior surface fuel bed is 2 m long, 80 cm wide, 5 cm deep, M=7.3%, ρ_{bulk} = 5.8 kg/m^3, σ = 4500 m^{-1}
- Raised chamise is 30 cm long, 80 cm wide, 30 cm tall. Base height is 25 cm M = 80%, ρ_{bulk} = 13.6 kg/m^3, σ = 4500 m^{-1}

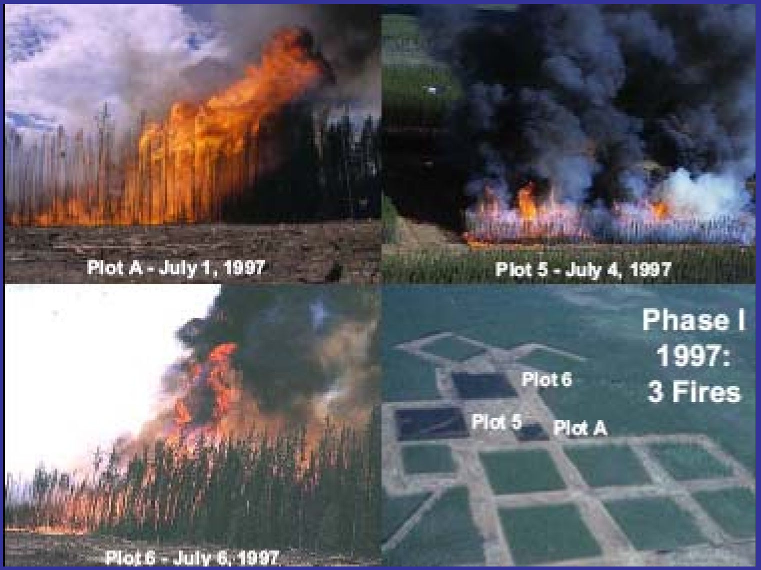
grid cell = 2 cm; 500,000 cells; 20 cpu hour for 120 s

International Crown Fire Modeling Experiments



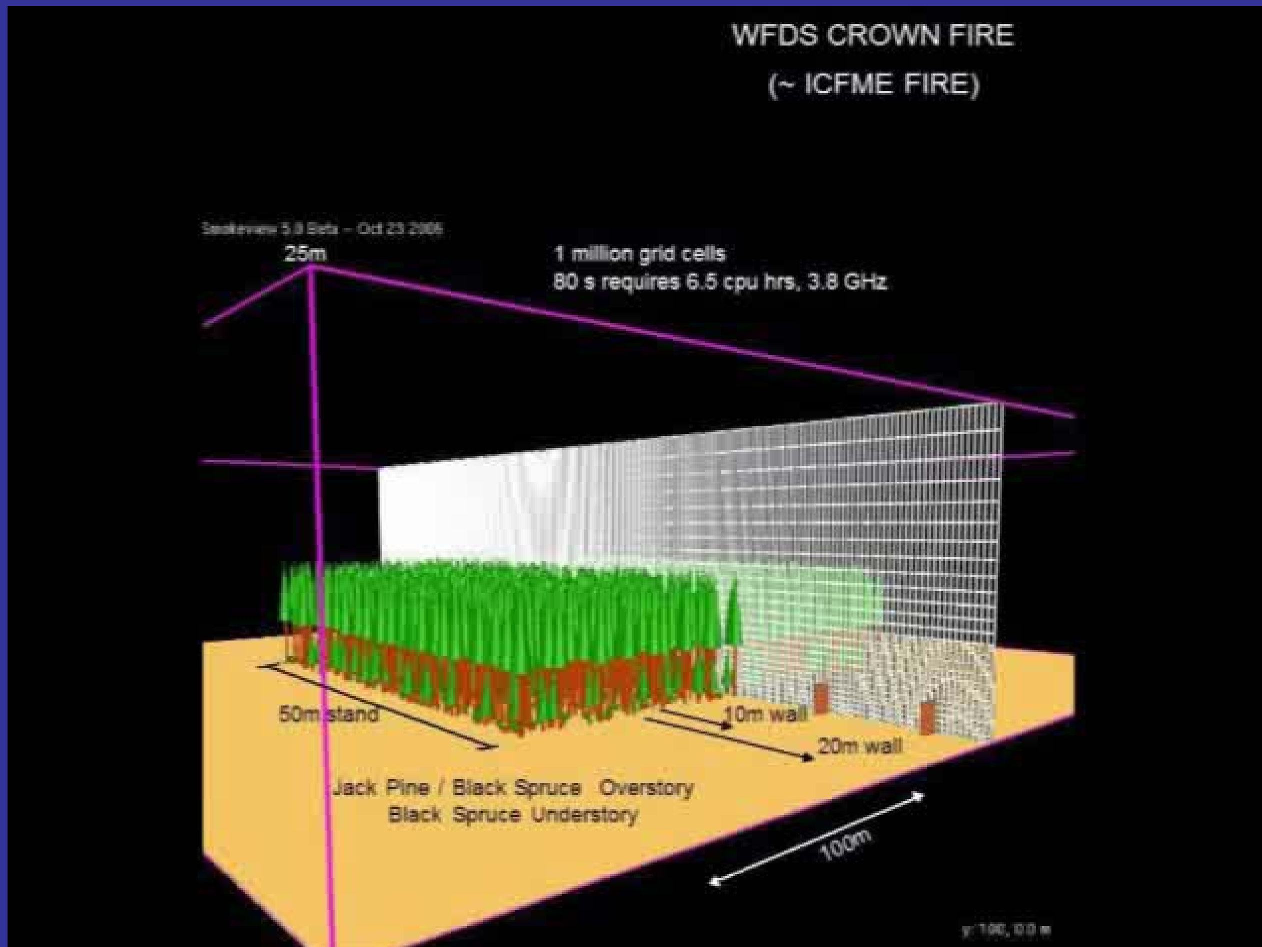
M. Alexander

- 9 plots, NWT Canada
- Jack pine / Black spruce overstory
- Black spruce understory



M. Alexander

WFDS Approximation to ICFME Structure Ignition Experiment

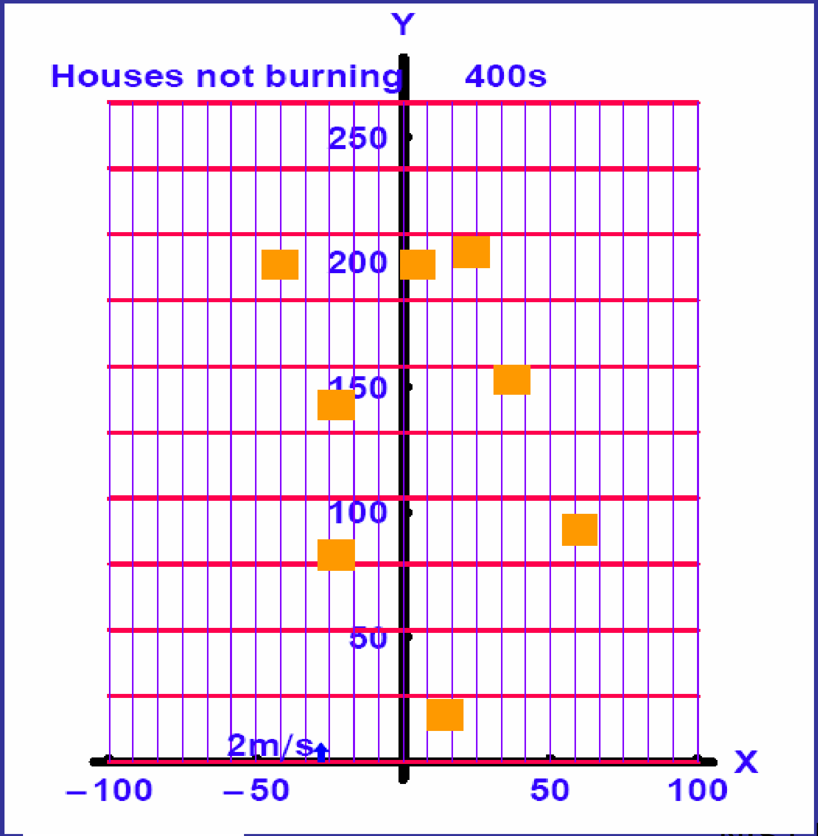


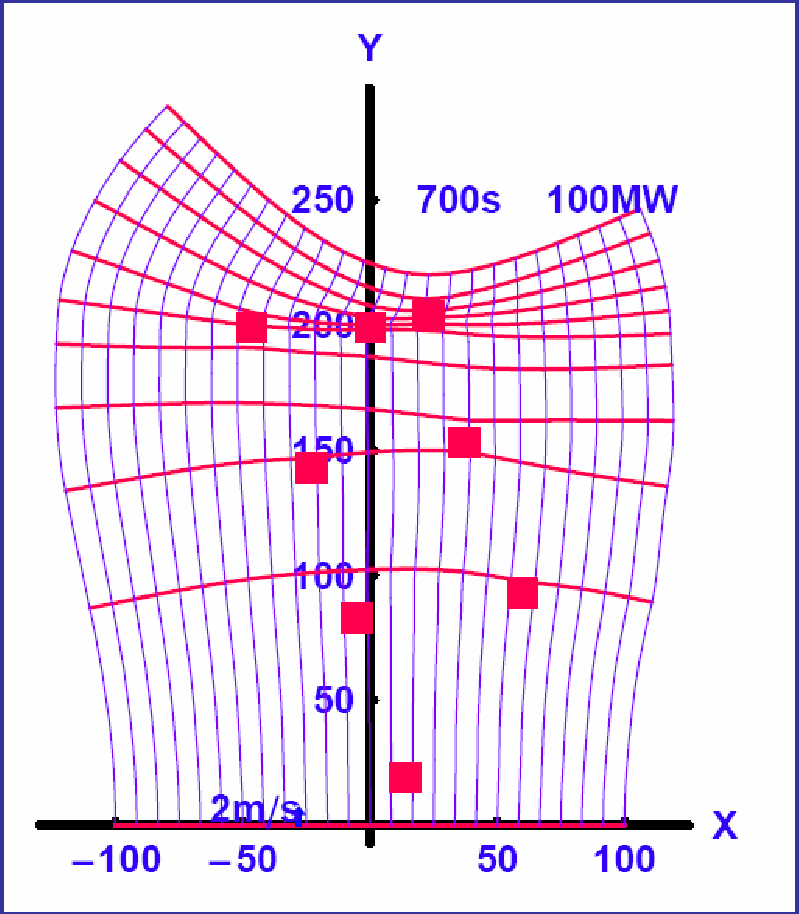
Level 2 Model: Simple Dynamical WUI Fire Model

- Disparate wildland & structural HRRs
- Disparate time scales for burning
  - Wildland fuels – minutes
  - Structural fuels – hours
- Compute house-fire entrainment effects on grassland fire
- Empirical spread rate formula for grass fire

Simple Dynamical Model

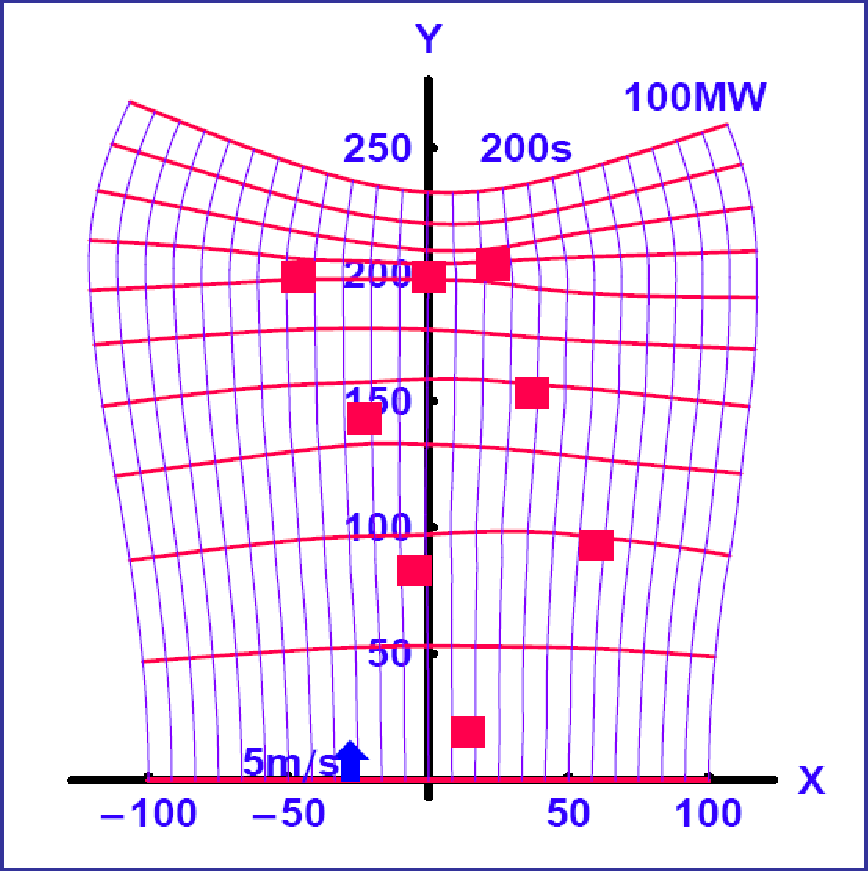
Wind-blown (2 m/s) line fire propagating past houses
Left – houses not burning; interval between lines = 40 s
Right - houses burning @ 100 MW/house; interval = 70 s
(700 s real time required 423 CPU s to compute)



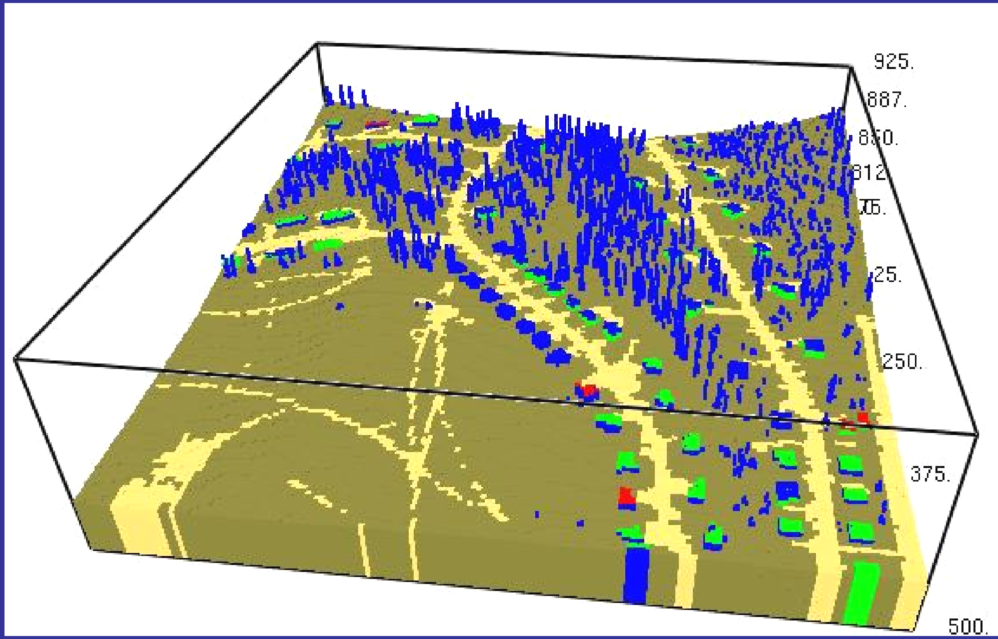


Simple Dynamical Model

Wind-blown (5 m/s) line fire propagating past houses
Left – houses not burning; interval between lines = 15 s
Right - houses burning @ 100 MW/house; interval = 20 s
(200 s real time required 228 CPU s to compute)



Models Inputs for WUI Community



Worley, Idaho

- Vegetative and structural fuels and terrain mapped by the Couer d’Alene Indian Tribe GIS program.
- Structures colored according to NFPA 1144 rating.
- 3-D rendering by NIST’s Smokeview visualization tool.

Thank you!

Questions?

Objectives of WUI Project

- Develop usable tools (models, datasets) to assess and predict the risk of communities and structures to WUI fires.
- Provide tools to incident managers, forest managers, community planners, and others to reduce impact of WUI fires.
- Provide a scientific basis for WUI building standards and codes.

Why is the problem hard to solve?

regional

community

Photo by JOHN GIBBINS / Union-Tribune
Cedar Fire about to engulf the Scripps Ranch residential community

residence fuels

basic vegetative fuel elements

- Range of scales and multitude of driving factors ⇨ usable tools
- Institutional boundaries has made OA funding difficult to obtain.

Current Approach to Home Risk Mitigation: Rule Based Checklists

Firewise Landscaping Checklist

When designing and installing a firewise landscape, consider the following:

- ❑ Local area fire history.
- ❑ Site location and overall terrain.
- ❑ Prevailing winds and seasonal weather.
- ❑ Property contours and boundaries.
- ❑ Native vegetation.
- ❑ Plant characteristics and placement (duffage, water and salt retention ability, aromatic oils, fuel load per area, and size).
- ❑ Irrigation requirements.

To create a firewise landscape, remember that the primary goal is fuel reduction. To this end, initiate the zone concept. Zone 1 is closest to the structure; Zones 2-4 move progressively further away.

- ❑ Zone 1. This well-irrigated area encircles the structure for at least 30' on all sides, providing space for fire suppression equipment in the event of an emergency. Plantings should be limited to carefully spaced low flammability species.
- ❑ Zone 2. Low flammability plant materials should be used here. Plants should be low-growing, and the irrigation system should extend into this section.
- ❑ Zone 3. Place low-growing plants and well-spaced trees in this area, remembering to keep the volume of vegetation (fuel) low.
- ❑ Zone 4. This furthest zone from the structure is a natural area. Selectively prune and thin all plants and remove highly flammable vegetation.

Also remember to:

- ❑ Be sure to leave a minimum of 30' around the house to accommodate fire equipment, if necessary.
- ❑ Widely space and carefully situate the trees you plant.
- ❑ Take out the "ladder fuels" — vegetation that serves as a link between grass and tree tops. This arrangement can carry fire to a structure or from a structure to vegetation.
- ❑ Give yourself added protection with "fuel breaks" like driveways, gravel walkways, and lawns.

When maintaining a landscape:

- ❑ Keep trees and shrubs properly pruned. Prune all trees so the lowest limbs are 6' to 10' from the ground.
- ❑ Remove leaf clutter and dead and overhanging branches.
- ❑ Mow the lawn regularly.
- ❑ Dispose of cuttings and debris promptly, according to local regulations.
- ❑ Store firewood away from the house.
- ❑ Be sure the irrigation system is well maintained.
- ❑ Use care when refueling garden equipment and maintain it regularly.
- ❑ Store and use flammable liquids properly.
- ❑ Dispose of smoking materials carefully.
- ❑ Become familiar with local regulations regarding vegetation clearances, disposal of debris, and fire safety requirements for equipment.
- ❑ Follow manufacturers' instructions when using fertilizers and pesticides.

Access additional information on the Firewise home page: ***www.firewise.org***

Please see the other side of this sheet for the ***Firewise Construction Checklist.***

FIREWISE Landscaping

Firewise Construction Checklist

When constructing, renovating, or adding to a firewise home, consider the following:

- ❑ Choose a firewise location.
- ❑ Design and build a firewise structure.
- ❑ Employ firewise landscaping and maintenance.

To select a firewise location, observe the following:

- ❑ Slope of terrain; be sure to build on the most level portion of the land, since fire spreads more rapidly on even minor slopes.
- ❑ Set your single-story structure at least 30 feet back from any ridge or cliff; increase distance if your home will be higher than one story.

In designing and building your firewise structure, remember that the primary goals are fuel and exposure reduction. To this end:

- ❑ Use construction materials that are fire-resistant or non-combustible whenever possible.
- ❑ For roof construction, consider using materials such as Class-A asphalt shingles, slate or clay tile, metal, cement and concrete products, or terra-cotta tiles.
- ❑ Constructing a fire-resistant sub-roof can add protection as well.
- ❑ On exterior wall facing, fire resistive materials such as stucco or masonry are much better choices than vinyl which can soften and melt.
- ❑ Window materials and size are important. Smaller panes hold up better in their frames than larger ones. Double pane glass and tempered glass are more relaible and effective heat barriers than single pane glass. Plastic skylights can melt.
- ❑ Install non-flammable shutters on windows and skylights.
- ❑ To prevent sparks from entering your home through vents, cover exterior attic and underfloor vents with wire screening no larger than 1/8 of an inch mesh. Make sure undereave and soffit vents are as close as possible to the roof line. Box in eaves, but be sure to provide adequate ventilation to prevent condensation.
- ❑ Include a driveway that is wide enough to provide easy access for fire engines (12 feet wide with a vertical clearance of 15 feet and a slope that is less than 5 percent) . The driveway and access roads should be well-maintained, clearly marked, and include ample turnaround space near the house. Also provide easy access to fire service water supplies, whenever possible.
- ❑ Provide at least two ground level doors for easy and safet exit and at least two means of escape (i.e., doors or windows) in each room so that everyone has a way out.
- ❑ Keep gutters, eaves, and roofs clear of leaves and other debris.
- ❑ Make periodic inspections of your home, looking for deterioration such as breaks and spaces between roof tiles, warping wood, or cracks and crevices in the structure.
- ❑ Periodically inspect your property, clearing dead wood and dense vegetation at distance of at least 30 feet from your house. Move firewood away from the house or attachments like fences or decks.

Any structures attached to the house, such as decks, porches, fences, and outbuildings should be considered part of the house. These structures can act as fuel bridges, particularly if constructed from flammable materials. Therefore, consider the following:

- ❑ If you wish to attach an all-wood fence to your house, use masonry or metal as a protective barriers between the fence and house.
- ❑ Use metal when constructing a trellis and cover it with high-moisture, low flammability vegetation.
- ❑ Prevent combustible materials and debris from accumulating beneath patio decks or elevated porches. Screen or box-in areas below patios and decks with wire screen no larger than 1/8 inch mesh.
- ❑ Make sure an elevated wooden deck is not located at the top of a hill where it will be in direct line of a fire moving up slope. Consider a terrace instead.

Access additional information on the Firewise home page: ***www.firewise.org***

Please see the other side of this sheet for the ***Firewise Landscaping Checklist.***

FIREWISE Construction

- Firewise Plant lists for 14 states.

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Tree burn experiments: Different moistures 2.4 m Trees

Moisture = 50 %

14%

Two moisture regimes:

I. 30% ≤ M ≤ 70%
- partially consumed crown
- only foliage burns
- no firebrands

II. M ≤ 30%
- fully consumed crown
- foliage, twigs < 10mm burn
- firebrands produced

Tree with M > 80% did not sustain fire spread with this ignition method.

Tree Burns: Experimental and WFDS Mass Loss Rate Histories

2.4 m tall trees; ρ_b=2.8

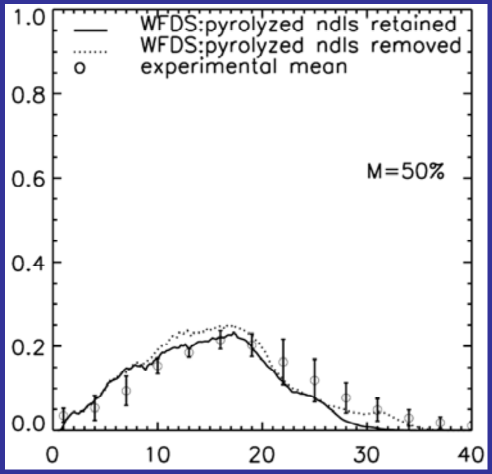
4.5 m tall trees

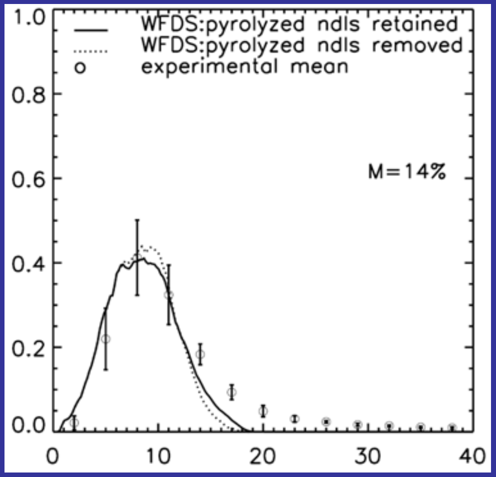
Mavg = 50%

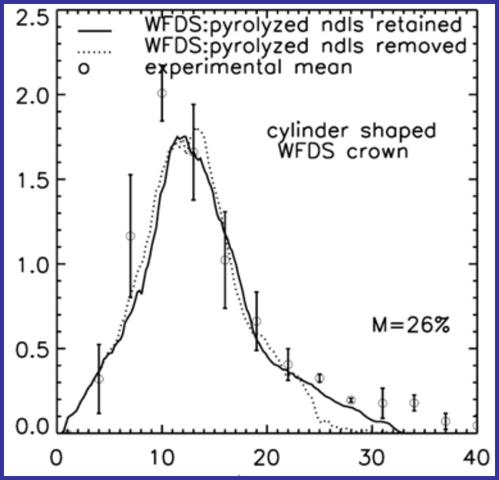
Mavg = 16%

Mavg = 26%

mass loss rate kg/s







time, s

time, s

time, s

- ρ_b= 2.8 kg/m^3
- 3/4 cpu hour for 30 s
- grid cell = 7.5 cm
- 128,000 cells

- ρ_b= 1.8 kg/m^3
- 3.5 cpu hours for 30 s
- grid cell = 10 cm
- 320,000 cells

Table of Experimental and WFDS Results

Height of raised fuel base, cm	Imposed wind speed, m/s	Ignition success	
		Experiment	WFDS
25	0	Yes	Yes
25	1.45	Yes	Yes
25	1.85	No	No
35	0	Yes	Yes
35	1.45	No	No
45	0	No	No
45	1.45	No	No

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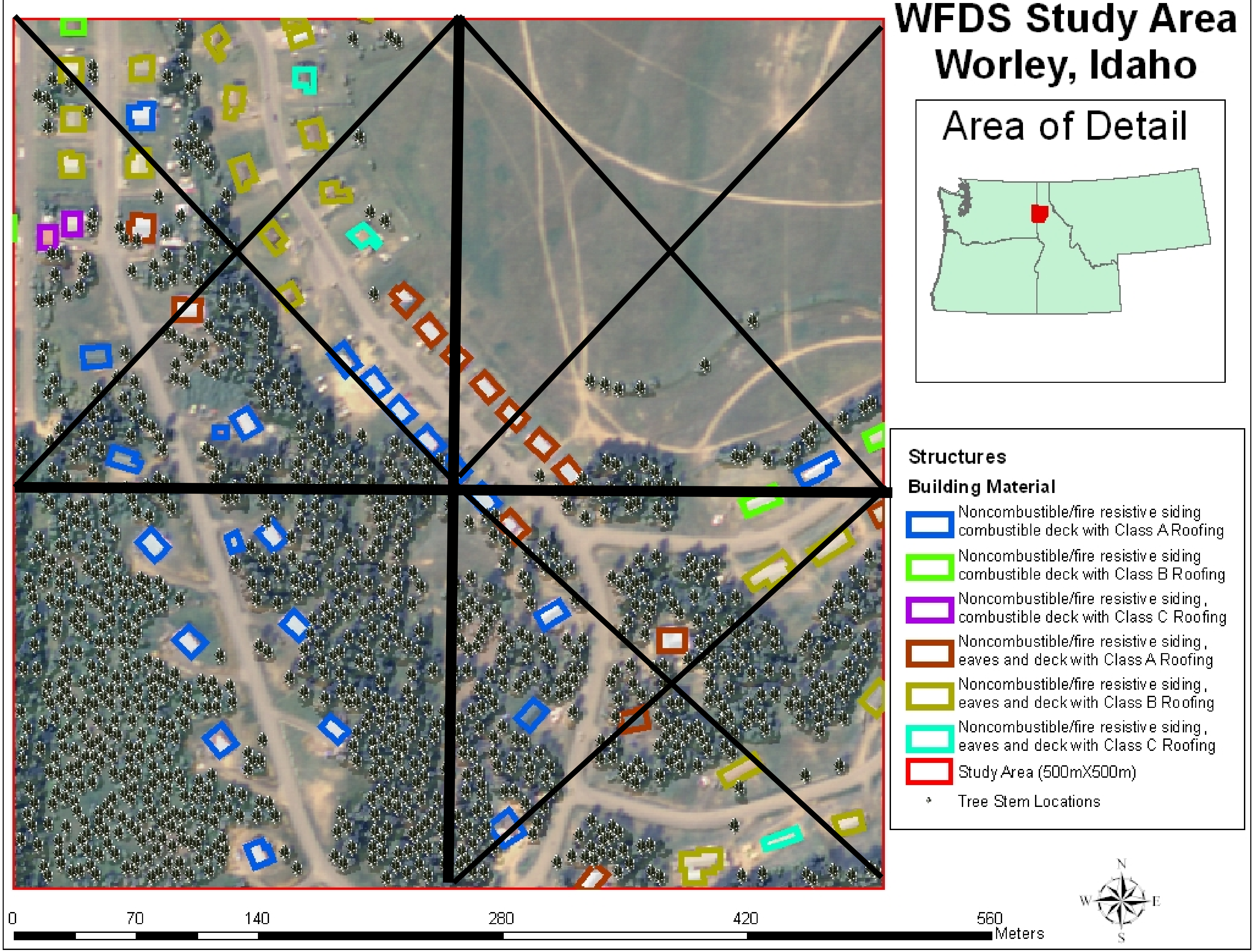

WFDS Study Area
Worley, Idaho
Area of Detail
Structures
Building Material
Noncombustible/fire resistive siding combustible deck with Class A Roofing
Noncombustible/fire resistive siding combustible deck with Class B Roofing
Noncombustible/fire resistive siding, combustible deck with Class C Roofing
Noncombustible/fire resistive siding, eaves and deck with Class A Roofing
Noncombustible/fire resistive siding, eaves and deck with Class B Roofing
Noncombustible/fire resistive siding, eaves and deck with Class C Roofing
Study Area (500mX500m)
Tree Stem Locations
0
70
140
280
420
560
Meters
N
W
E
S